Penetrating Neck Injuries Treated at a U.S. Role 3 Medical Treatment Facility in Afghanistan During Operation Resolute Support

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ABSTRACT

Introduction:
Military trauma registries can identify broad epidemiological trends from neck wounds but cannot reliably demonstrate temporal casualty from clinical interventions or differentiate penetrating neck injuries (PNI) from those that do not breach platysma.

Materials and Methods:
All casualties presenting with a neck wound to a Role 3 Medical Treatment Facility in Afghanistan between January 1, 2016 and September 15, 2019 were retrospectively identified using the Emergency Room database. These were matched to records from the Operating Room database, and computed tomography (CT) scans reviewed to determine damage to the neck region.

Results:
During this period, 78 casualties presented to the Emergency Room with a neck wound. Forty-one casualties underwent surgery for a neck wound, all of whom had a CT scan. Of these, 35/41 (85%) were deep to platysma (PNI). Casualties with PNI underwent neck exploration in 71% of casualties (25/35), with 8/25 (32%) having surgical exploration at Role 2 where CT is not present. Exploration was more likely in Zones 1 and 2 (8/10, 80% and 18/22, 82%, respectively) compared to Zone 3 (2/8, 25%).

Conclusion:
Hemodynamically unstable patients in Zones 1 and 2 generally underwent surgery before CT, confirming that the low threshold for exploration in such patients remains. Only 25% (2/8) of Zone 3 PNI were explored, with the high negative predictive value of CT angiography providing confidence that it was capable of excluding major injury in the majority of cases. No deaths from PNI that survived to treatment at Role 3 were identified, lending evidence to the current management protocols being utilized in Afghanistan.

INTRODUCTION

Neck wounds sustained in combat represent between 3 and 18% of all those who survived to assessment at a U.S. Medical Treatment Facility (MTF) in Afghanistan.[1–5] A large proportion of those wounds however are superficial, and a recent analysis demonstrated that the incidence of actual penetrating neck injury (PNI), commonly defined as one in which the platysma layer is breached,[6] was approximately 5% between 2004 and 2011.[7] The neck is further subdivided into three zones, as first described by Monson et al.[8] A large U.S. analysis of deaths on the battlefield between 2001 and 2011 demonstrated that 8% of the prehospital deaths caused by potentially survivable injuries were attributable to external hemorrhage from the cervical region, although it did not subdivide it by zones of the neck.[9]

Current U.S. military doctrine supports deploying and organizing health services at levels with progressive capabilities referred to as the four roles of care (Roles 1–4).[10] Role 1 providers deliver specialized first aid, triage, and resuscitation for neck wounds. Damage control surgery is delivered at Role 2 by general and orthopedic surgeons. Role 3 hospitals, enable subspecialty surgical with a head and neck trauma team comprised of a neurosurgeon, otolaryngologist, and oral maxillofacial surgeon. Since the start of Operation Resolute Support on January 1, 2015, neck injuries in the Bagram area of responsibility have been managed by U.S. Air Force otolaryngology (ENT) and general surgeons,[11] with the assistance of U.K. oral and maxillofacial surgeons since February 2019. The rules of engagement enable provision of medical support to all U.S. and coalition forces, Afghan military, or civilians working with U.S. and coalition forces, and in some instances Afghan civilians.[12]

The management of PNI in a deployed military setting to a degree remains dependent on the resources available and

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the capabilities of the deployed surgical team.[7,13–16] Debate includes vascular technique (ligation of carotid artery injuries versus repair in terms of reperfusion risk), choice of incision, and requirement for a surgical airway (such as conversion of battlefield cricothyroidotomy to definitive tracheotomy). For example, in the deployed setting, angiographic intervention is rarely available and access to PNI in Zone 1 (cricoid to clavicle) and Zone 3 (lower border of mandible to base of skull) can be challenging.[17,18] Mandatory surgical exploration of PNI on deployment is advocated by some authorities.[19,20] Others have suggested a more conservative approach, with serial monitoring of a stable patient with no adverse features on computed tomography (CT) angiography, endoscopy, and surgical exploration only if the workup is positive or equivocal.[4,14,19] There is currently a drive in the U.S. Military Health System to develop Combat Casualty Care Knowledge, Skills, and Abilities that would prioritize surgical readiness and ensure surgeons from all specialties are equipped with the knowledge and skills to deploy. In the U.S. military, acute trauma patient care is guided by the Joint Trauma System Clinical Practice Guidelines.[21]

Previous analyses of the management of PNI in Iraq and Afghanistan have either been based on analysis of the Joint Trauma Registry[7,22–24] or surgical logbooks.[19] Trauma registries utilize Abbreviated Injury Severity codes to identify broad epidemiological trends but cannot reliably demonstrate temporal casualty from clinical interventions. For example, it cannot say if a CT scan was taken before or after surgical exploration, nor what damage was found intraoperatively or by investigations such as endoscopy. There is also no specific Abbreviated Injury Severity code for a neck injury that breaches platysma (PNI); PNI can only be assumed by the presence of damage to structures deep to platysma. The aim of this study was to review the contemporary clinical management of PNI at a mature U.S. Military Role 3 MTF in Afghanistan to act as a baseline for future military operations.

METHODS

This study adhered to the Declaration of Helsinki. Informed patient consent was not required as a result of the nature of the study. This project was approved as a Performance Improvement initiative by the U.S. Central Command Command Surgeon. It was reviewed by the U.S. Army Medical Research and Development Command's Office of Research Protections, Institutional Review Board Office, and given a Not Research Determination.

All casualties presenting with a neck wound to a Role 3 MTF in Afghanistan between January 1, 2016 and September 15, 2019 were retrospectively identified using the Emergency Room database. These were matched to records from the Operating Room (OR) database, and CT scans were reviewed to determine damage to the neck region. Inclusion criteria were all PNI managed at Role 3, whether they had been treated previously at Role 2 or not. Exclusion criteria were any neck wound that did not breach platysma. Hospital numbers and patient names were cross-referenced with surgical operative records derived from the deployed hospital TC2 database. Emergency Department records were used to identify discrepancies between temporary patient identifiers and casualties treated under local anesthesia in the Emergency Department alone. Casualties were defined as having hemodynamic instability if they had a systolic blood pressure below 80 mm Hg or required blood products at any point during evacuation or at Role 2 or 3. Outcome criteria included surgical exploration and mortality before evacuation from Role 3. Data analysis was undertaken using SPSS Statistics version 16 (IBM, New York, USA). Odds ratios were determined using a Chi-Square test with Yates' continuity correction and reported with *P*-values and confidence interval.

RESULTS

During this period, 78 casualties presented to the Emergency Room with a neck wound. Thirty-seven casualties did not undergo surgery, of which 9/37 had a CT scan; 0/9 had evidence of PNI. These 37 casualties were excluded from further analysis. Forty-one casualties underwent surgery for a neck wound, all of whom had a CT scan (Fig. 1). Of these, 35/41 (85%) were PNI. Treatment of neck wounds required 95 surgical procedures (range 1–4, mean 2) and 59 visits to the operating theater (range 1–2, mean 1.1). No deaths directly attributable to treated neck injuries were found. Of these, 25/35 (71%) casualties with PNI underwent neck exploration.

All 35 casualties with PNI sustained their injuries in battle (Table I). Gunshot wounds (GSW) were responsible for 22/35 (63%) PNI, followed by 13/35 (37%) from explosive devices (improvised explosive devices, rockets, and grenades). Of these, 15/22 (68%) GSWs were transcervical, and in 7/22 (32%), there was evidence that the bullet may have fragmented.

Of the 35 casualties that sustained PNI (Table II), Zone 2 was the most commonly entry wound location (22/35, 63%). The most common procedures performed on those 25 casualties with PNI who were explored (apart from wound closure) were repair of major vessel (6/25, 24%), ligation of major vessel (5/25, 20%), tracheal repair (5/25, 20%), and a single repair of an esophagus (4%). Ligation of minor neck vessels (anterior or external jugular) were noted in three casualties. Of the six repairs, all were either common or internal carotid artery. Of these, 1/6 was repaired by primary closure, the remaining 5/6 with autologous venous patches. When using patches, 3/5 were recorded as having temporary shunting.

Of the 35casualties with PNI, 25 (71%) underwent neck exploration (Fig. 1, Table III). The remaining 10/35 had a washout and primary closure alone. Eight out of 25 casualties (32%) had surgical exploration at Role 2 where CT is not present and subsequently had a CT when transferred to Role 3. Of those who underwent exploration at Role 2, 5/8 (63%) were treated as unstable as a result of their PNI. The remaining 3/8 (37%) had transcervical GSWs, but no records were found as to why exploration was performed. All eight

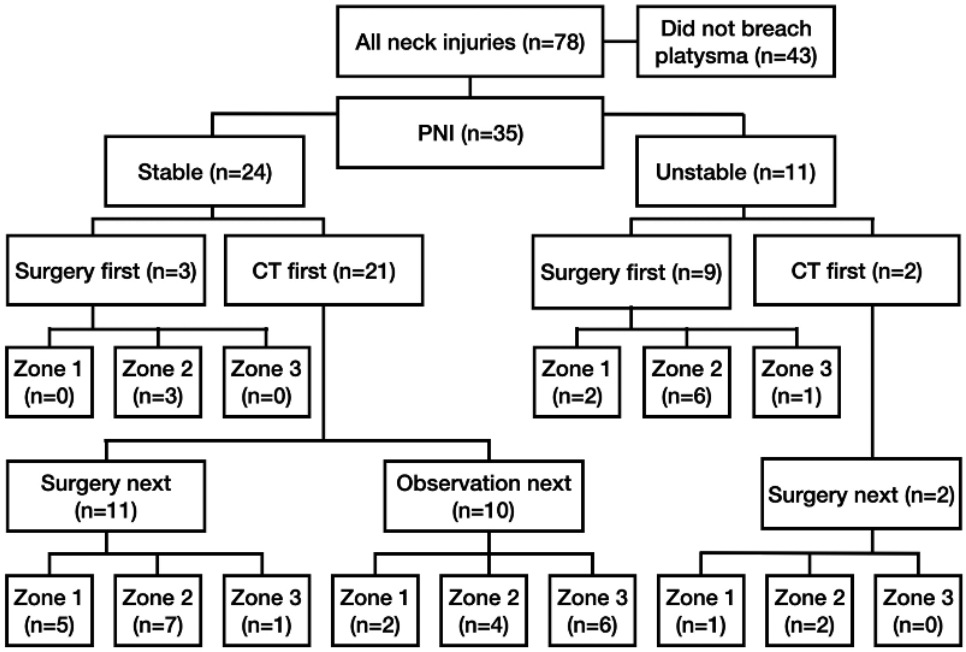

FIGURE 1. Preoperative disposition on decision to perform surgery related to computed tomography. This includes Role 2 where no computed tomography scanner is present. Some casualties had multiple neck zone entry points hence why they are not cumulative.

TABLE I. Epidemiology of Those Undergoing Surgical Procedures to the Neck. Explosive Devices Included Improvised Explosive Devices, Grenades, and Rockets

Nation	Explosive device (battle)	Gunshot wound (battle)	All
U.S. military	2	1	3
Other coalition military	1	0	1
Afghan National Army	9	16	25
Local civilian	1	5	6
All neck surgical procedures	**13**	**22**	**35**

TABLE II. Penetrating Neck Injury (PNI) Subdivided by Entry Location and Mechanism of Injury

Entry zone	Explosive device	Gunshot wound	All
1 only	2	5	7
1 + 2	0	1	1
2 only	8	11	19
2 + 3	0	0	0
3 only	2	4	6
1 + 2 + 3	1	1	2
All PNI	**13**	**22**	**35**

TABLE III. CT Result When Performed at Role 3 and Clinical Management. Those 8/35 Casualties Treated at Role 2 First Are Excluded. Some Casualties Had Multiple Neck Zone Entry Points Hence Why the Columns Are Not Cumulative

Effect of CT on subsequent management	Zone 1	Zone 2	Zone 3	All
No damage on CT but proceeded to exploration	2	6	0	8
Damage on CT and proceeded to exploration	3	7	3	9
No damage on CT and no exploration	0	3	4	7
Damage on CT and no exploration	2	1	1	3
All casualties managed at Role 3 alone	**7**	**17**	**8**	**27**

having surgery at Role 2 had further surgery at Role 3. Those 12 casualties having neck exploration for PNI before CT were statistically more likely to be unstable or have hard signs present ($P = .004$, OR = 8.09, CI = 2.25–121.23) than those 13 that did not. Two casualties had CT before neck exploration despite being unstable—both were caused by GSWs entering at the base of Zone 1. Exploration was more likely in Zones 1 and 2 (8/10, 80% and 18/22, 82% respectively) compared to Zone 3 (2/8, 25%). Zone 1 injuries were all managed by an incision along sternocleidomastoid, with a midline sternotomy extension performed for three casualties. Both Zone 3 injuries treated surgically were described as being a superior extension of the SCM incision, of which one ligated the

bleeding vessel and the other was packed and subsequently bleeding stopped.

Twenty-seven casualties with PNI were managed only at Role 3 and not previously treated at Role 2 (Table III). Four casualties who were unstable went straight to Role 3; all had surgery before CT. Of the 27 casualties, 17 (63%) proceeded to have surgery. Overall the 27 casualties with PNI, those with damage on CT were more likely to proceed to surgery than if no damage was seen but the result was not statistically significant ($P = .119$, OR = 243, CI = 0.92–35.5). However, when analyzing those 12 casualties in which damage was seen on CT but did not proceed to surgery, there was no statistical difference whether Zone 1 or Zones 1 + 3 were affected ($P = .48$, OR = 0.5, CI = 0.08–2.517).

CT had a positive predictive value (PPV) of 44.4% (95% CI: 26.1–64.4%) and negative predictive value (NPV) of 88.9% (95% CI: 56.8–97.9%) for vascular damage subsequently found during surgery (Table S1). The seven casualties treated at Role 2 first were excluded as the surgery may have affected interpretation of CTs taken in Role 3.

CT had a positive PPV of 66.7% (95% CI: 18.6–94.6%) and NPV of 80.0% (95% CI: 65.8–89.3%) for aerodigestive damage subsequently found during surgery or on endoscopy (Table S2). Again the seven casualties treated at Role 2 first were excluded as the surgery may have affected interpretation of CTs taken in Role 3.

DISCUSSION

This article aims to provide the current state of play regarding the management of PNI in an austere setting in Afghanistan. This analysis differs from those in earlier conflicts,[13,14] in that during the period covered in this article (2016–2019), the majority of those injured were local nationals. The most common cause of injury was found to be from GSWs (63%) which is different from articles published from earlier in the conflict where PNI was predominantly from explosive devices (57–64%).[7,13] Most U.S. and coalition military personnel would have been wearing ballistic neck collars during this period studied, which are designed to preventing the perforation of explosive fragments into the neck.[25] Based on previous analyses that have shown that neck collars can prevent fragment perforation into Zones 1 and 2 of the neck,[25] in this analysis up to 10 PNI could have been prevented by the wearing of ballistic neck collars.

In our series, 71% (25/35) of PNI were explored, higher than that found in civilian practice (19%).[26] Exploration was more likely in Zones 1 and 2 (80% and 82%, respectively) compared to Zone 3 (25%). The higher incidence reflects a number of potential reasons. The first is that many of these explorations took place in Role 2 where a CT scan was not present and therefore could not exclude damage. A second reason is that some casualties may have sustained polytrauma with resultant hemodynamic instability of which it was not possible to exclude the neck as a cause. Third, there remains a widely held perception even to this day that there should be a lower threshold for neck exploration in the prehospital setting as a result of the unpredictability of the wound tracts, in particular those from explosive devices, in conjunction with potentially protracted evacuation timelines. Even in stable patients, some authors still advocate mandatory surgical exploration of such wounds.[19] Unnecessary explorations will occur with this approach, with Brennan et al. finding 31% of neck explorations had no damage.[19] However hard signs, such as an expanding hematoma, or hemodynamic instability remain the primary indications for surgery before CT.[6] In our series, 11/25 (44%) of those who underwent exploration had written documentation of hard signs or hemodynamic instability. Three casualties had surgical exploration at Role 2 without evidence of hard signs; all were transcervical GSWs. Although there may have been a lack of written documentation to suggest the indication for surgery, it may reflect that casualties with transcervical GSWs have a high probability of injury as a result of the energy transmission, despite continued debate in the civilian literature.[27] Two casualties had CT before neck exploration despite being unstable—both were caused by GSWs entering at the base of Zone 1. This reflects balancing the benefits of localizing a Zone 1 injury to direct the best intervention with the risks of prolonging surgery in an unstable casualty. All the other nine unstable patients had surgery before CT (6/9 were Zone 2).

CT plays an important role in the management of PNI in the deployed setting, with a deployed radiologist enhancing rapid diagnosis. The PPV for vascular injury was 44%, lower than that described in a recent systematic review and meta-analysis (97%).[28] It did however have a high NPV (90%), similar to civilian series which have reported figures up to 98%.[28–30] There are no military studies to compare the findings of our study to and therefore the authors assume that the value reflects factors intrinsic to ballistic trauma to the neck in an austere setting. The most common reason is streak artifact from retained metallic shrapnel or bullet fragments,[31] in cases of laryngeal injury, extensive extralaryngeal and endolaryngeal soft tissue swelling and hematoma may conceal the site of direct injury.[32] CT is best additionally supplemented by endoscopy, in particular for suspected aerodigestive injury.[6,33] In our series, CT had a positive PPV of 67% and an NPV of 80% for aerodigestive damage subsequently found during surgery; this compares favorably with comparable civilian figures for CT esophagoscopy with a PPV of 40–79% and NPV of 82–100%.[26,33,34] It is recognized though that the numbers available to produce these values in our study are low.

Neck zones have traditionally been used to assist in determining surgical approach, with Zones 1 and 3 being technically more challenging to treat, which has, in turn, resulted in a higher threshold for surgical intervention. However, in our series, there was no difference in the odds of injuries being treated in one zone rather than another. The importance of neck zones in determining interventions is debated in civilian practice, with the "no zone" approach adopted in some

centers. Such an approach, however, may not be suitable in the deployed theater, as in particular percutaneous endovascular interventions are generally not available in a deployed setting.

More vascular repairs occurred in comparison to ligation, which is different from most previous descriptions.[7,14,15,35] It may have, however, reflected that more arterial injuries were described than venous injuries, the former of which are more likely to be repaired or grafted if potentially possible. This positive evolution of PNI treatment is encouraging and likely reflects the deployment of both trauma and general surgeons to Role 3 MTFs. Only a single esophageal repair was described, but this may reflect a low incidence of injury. Such surgery can be challenging, and traditionally has been deferred for U.S. and coalition casualties until evacuation to Germany or the United States. With the greatest proportion of casualties now being local nationals, definitive esophageal repair in theater is a skill set needed at Role 3 facilities in Afghanistan.

We accept there are a number of potential limitations to this analysis. Operative records were often very brief, particularly those who were transferred from Role 2. We have not provided extracervical injuries or how many blood products were provided because these could not be accurately determined from the clinical records. However, senior review of the case notes would strongly suggest that in the absence of severe associated injuries necessitating immediate treatment, evacuation to Role 3 for a CT scan provided improved presurgical planning and even prevented unnecessary surgery, even in casualties with instability attributable to PNI. Further analysis utilizing physiological data, time from injury, and extracervical injuries should be undertaken to determine clinical outcomes of those taken directly to Role 2 or to Role 3 with a CT first.

CONCLUSIONS

The majority of hemodynamically unstable patients with PNI to Zones 1 and 2 underwent surgery before CT, confirming that the low threshold for exploration in such patients remains. Only 25% (2/8) of Zone 3 PNI were explored, with the high NPV of CT angiography providing confidence that it was capable of excluding major injury in the majority of cases. No deaths from PNI that survived to treatment at Role 3 were identified, lending evidence to the current management protocols being utilized in Afghanistan.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *Military Medicine* online.

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CONFLICT OF INTEREST STATEMENT

The authors have no declared conflict of interest in the collection and writing up of these results. Permission to publish has been granted by the US Department of Defense and the UK Ministry of Defence.

CONTRIBUTOR STATEMENT

Planning: JB, WG.

Conducting: JB, WG.

Reporting: JB, WG, JD.

LEVEL OF EVIDENCE STATEMENT

Level 3: retrospective study with up to two negative criteria.

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